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Observations on the Life History of the Endangered Hawaiian Vetch (*Vicia menziesii*) (Fabaceae) and Its Use by Birds[1]

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ABSTRACT: The reproductive events in a colony of the rare and localized Hawaiian vetch were studied for their relevance to the survival of the species. About 85 individuals were discovered on the island of Hawaii—a substantial increase in the number of known individuals. The species flowers prolifically, but individuals apparently do not produce flowers until they are about 2 to 3 years old. Our study shows that the species appears to be susceptible to herbivore damage and suggests that this is probably the major limiting factor in its present limited distribution. Native birds were found to use the flowers, probably as a source of nectar. We speculate that if, as seems at least possible, the species was formerly more widespread, it was probably a very important food source for native birds before the advent of herbivorous mammals. It is hoped that the species can be restored to its previous state of abundance for reasons of its esthetic qualities and as a valuable food source for wildlife.

ONE OF THE RAREST PLANTS in the world, the Hawaiian vetch (*Vicia menziesii* Sprengel), was known until recently from only about a dozen individuals collected over the years. The species is a vine, growing at times to 10 or more meters in maximum length, and producing at maturity many racemose inflorescences of attractive reddish flowers (Figure 1). *Vicia* belongs to the pea family, many members of which are known for their palatability to grazing animals, and *V. menziesii* is probably no exception. Introduced grazing animals may have played a major role in the present paucity of individuals surviving in Hawaii.

Since 1972, 3 colonies have been found (Jacobi and Warshauer, pers. comm.), all within 1 km of each other between 1500 m and 1750 m on the slopes of Mauna Loa, Hawaii, on lands of the Bernice P. Bishop Estate. One colony is located in the Kilauea Forest Reserve and consists of "5 or 6 mature vines ... and perhaps a dozen seedlings ... scattered over an area of not more than one hectare" (C. H. Lamoureux, pers. comm.). The other 2 colonies are located about 1.3 km away on the Keauhou Ranch. One comprises about 6 individuals in an area of about 0.25 ha (Warshauer, pers. comm.), and the other, the colony reported on in this paper, in 1977 contained about 85 individuals. These colonies are in a mixed ʻōhiʻa-lehua (*Metrosideros collina* subsp. *polymorpha*) and koa (*Acacia koa*) forest with rainfall of about 1500 mm to 2500 mm annually. Logging and grazing have modified the forest extensively in the Keauhou Ranch area. These activities have resulted in the reduction of native plant cover to about 50 percent as compared with nearby unlogged areas.

The distribution of the species' close relatives is unusual (Lassetter and Gunn 1979); apparently *V. menziesii* is most closely related to *V. nigricans* Hooker & Arnott of Chile and Argentina, and *V. gigantea* Hooker of the Pacific Northwest of North America.

Virtually nothing is known about the life history of the Hawaiian vetch. Recently it has been officially named an "endangered" species (U.S. Fish and Wildlife Service 1978), the first plant species in the Hawaiian Islands to achieve this status. This study documents

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several aspects of the biology of the Hawaiian vetch that may help in the management and recovery of this rare species.

MATERIALS AND METHODS

In 1977, we inventoried Hawaiian vetch plants found in our colony, recording growth habits, reproductive status, and measurements. The size of each plant was determined by measuring all live branches of the growing plants. Maximum length is the distance from the base of the plant, along the stems, to the tip of the longest branch.

The stages of flowering and pod (legume) formation were arbitrarily divided into 13 categories (Figure 1). These stages are (1) flower bud barely developed; (2) sepals open, tip of petals may show; (3) petals in the process of emerging from sepals; (4) petals mostly green, not open; (5) open petals, still largely greenish; (6) floral anthesis (ripe bloom), pinkish-red petals, mottled stamens emerging, stigma (pod) showing; (7) floral senescence (late bloom), petals falling, pod sometimes emerging; (8) young pod, just emerged from among sepals; (9) larger pod, chalky (glaucous) covering; (10) seeds enlarging, sepals shrivelled, chalky covering; (11) green and chalky pod, seeds very prominent, sepals shrivelled and black; (12) pod black and dried, seeds mature; and (13) green bare flower stalk (fruit abscission). Stage 13 usually follows stage 7, presumably when the flowers are not fertilized or, for other reasons, do not set seeds.

Using these arbitrary categories, we also assessed the timing of reproductive events on 4 mature individuals. All reproductive plants were visited on the following dates over a 50-day period: 20, 25, 28 July; 1, 4, 8, 11, 16, 19, 22, 25, 30 August; 2, 6, 8 September. Each raceme was characterized as to its stage of development (Figure 1). We noted if more than one stage was represented in a raceme. We interpolated the length of time between stages; each raceme of flowers or pods was usually a datum. If a flower cluster were stage 5 on day 15 and stage 6 on day 17, we assumed that transition actually took place on day 16. In the early stages of flowering, individual flowers differed in their timing to such an extent that, at times, each datum was a single flower.

RESULTS

Size and Growth Form of Plants

Eighty-five plants were found during the summer of 1977 and measured in October 1977 near the end of the species' presumed growing season. The plants ranged in maximum length from 0.1 m to 12.5 m, averaging 2.6 m (Figure 2). The median length was 1.2 m. The 10 flowering individuals averaged 8.7 m in maximum length, with a range from 5.1 m to 12.5 m.

In 83 plants categorized, 21 (25.3 percent) had more than one growing tip. No plants with a maximum length of less than 1 m had more than a single growing tip. One individual 9 m long, however, had still not branched. Cumulative length of all branches ranged from 0.1 m to 42.5 m in total length (Table 1), and the number of growing branch tips ranged from 1 to 18.

The growth form of the mature, flowering plant is as follows. The stem near the ground level ranges from 6 mm to 10 mm in diameter, and the bark is brown and fibrous. In climbing surrounding trees, in most cases live or dead 'ōhi'a-lehua, the vetch often takes circuitous routes. At times several meters of vine lie on the ground or over logs before ascending a tree. Although mature plants were often no more than 2 m to 4 m above the ground, a few individuals reached heights of from 6 m to 8 m. Most flowering plants branch laterally at various heights, creating a subcanopy of up to 10 m^2 under the 15 m- to 20 m-high 'ōhi'a-lehua canopy. A single mature plant thus can cover a substantial area.

The study area has been selectively logged for koa several times over the past 60 years. These logging operations, as well as mortality of koa and other trees from other causes, have left cattle-proof exclosures among downed logs. All stands of the vetch were found in

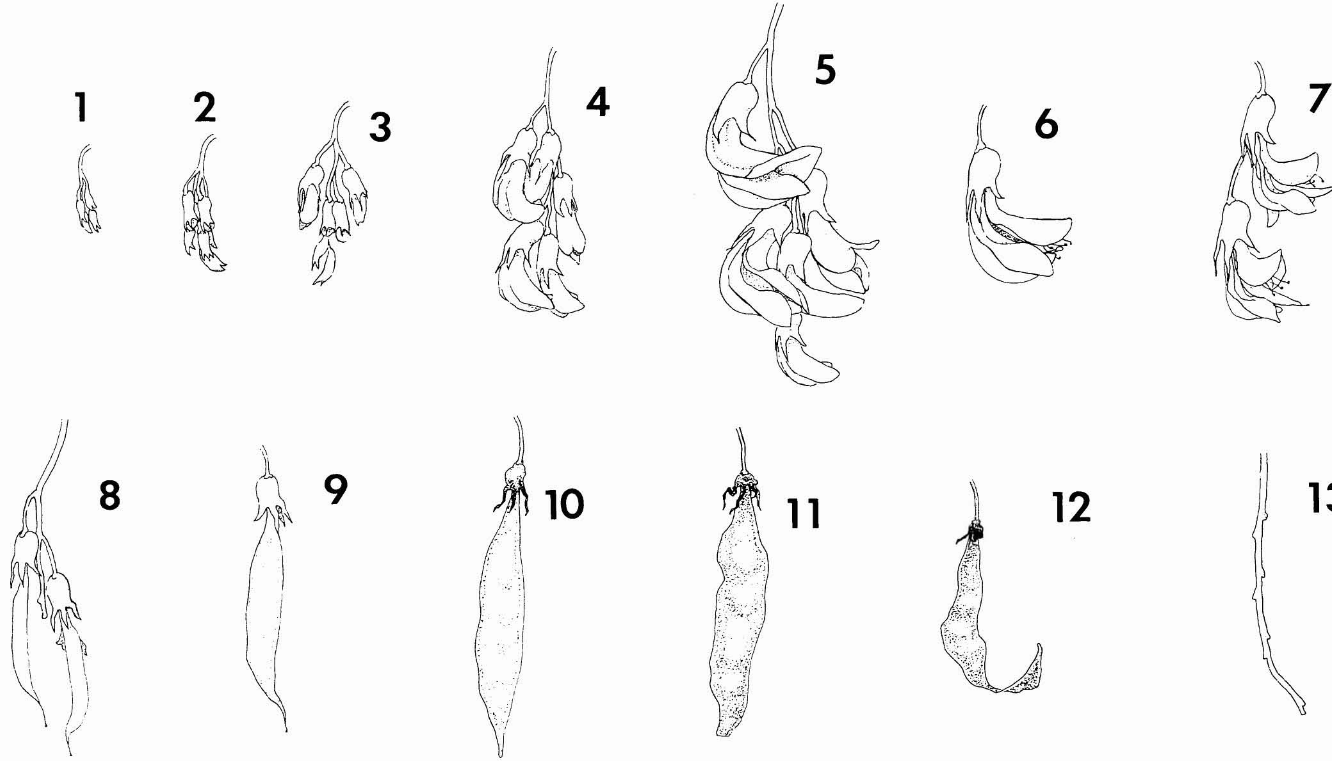

FIGURE 1. Stages of flowering and fruiting of the Hawaiian vetch.

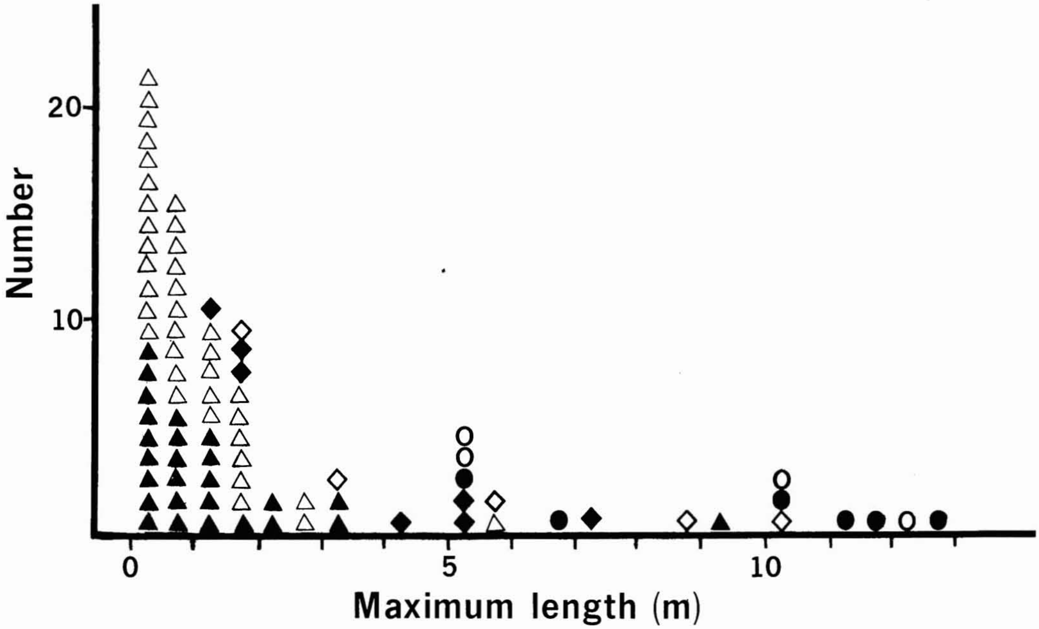

FIGURE 2. Maximum length of 85 Hawaiian vetch plants in October 1977: △ = unbranched plant; ◇ = branched plant; and ○ = flowering branched plant. A darkened symbol represents a plant that apparently died before May 1978.

TABLE 1

CHARACTERISTICS OF VETCH STANDS

STAND	TOTAL NUMBER PLANTS	NUMBER FLOWERING PLANTS	MAXIMUM LENGTH OF EACH PLANT $\bar{x}$	MAXIMUM LENGTH OF EACH PLANT range	CUMULATIVE LENGTH OF EACH PLANT $\bar{x}$	CUMULATIVE LENGTH OF EACH PLANT range	DAMAGED BY HERBIVORES (1977)	NUMBER DIED (to 5/30/77)
A	2	0	3.5	1.2–5.8	3.5	1.2–5.8	0	1
B	2	0	0.6	0.5–0.8	0.6	0.5–0.8	0	0
C	31	1	1.1	0.2–6.5	1.6	0.2–15.2	8	18(+2?)
D	17	1	2.4	0.1–11.9	2.3*	0.1–25.0*	0	5
E	2	1	7.9	5.4–10.4	26.2	13.6–38.7	0	0
F	20	6	4.5	1.0–12.5	8.6	1.0–42.5	0	7(+1?)
G	11	1	2.5	0.1–12.0	2.8	0.1–16.0	0	12(+1?)
Total	85	10						

*For 15 individuals.

areas where access by cattle was at least difficult, if not impossible.

Stand Size

We defined the stands arbitrarily as those whose members were at least 10 m from members of another stand, and less than 10 m apart themselves. By this definition, there were 7 stands—*A* through *G*—with an average populstion of 12.1 individuals (Table 1). Two of these stands—*A* and *B*—had no flowering individuals during the 1977 growing season; however, a nearby stand that was not documented during this season had flowering individuals. In other stands with at least one

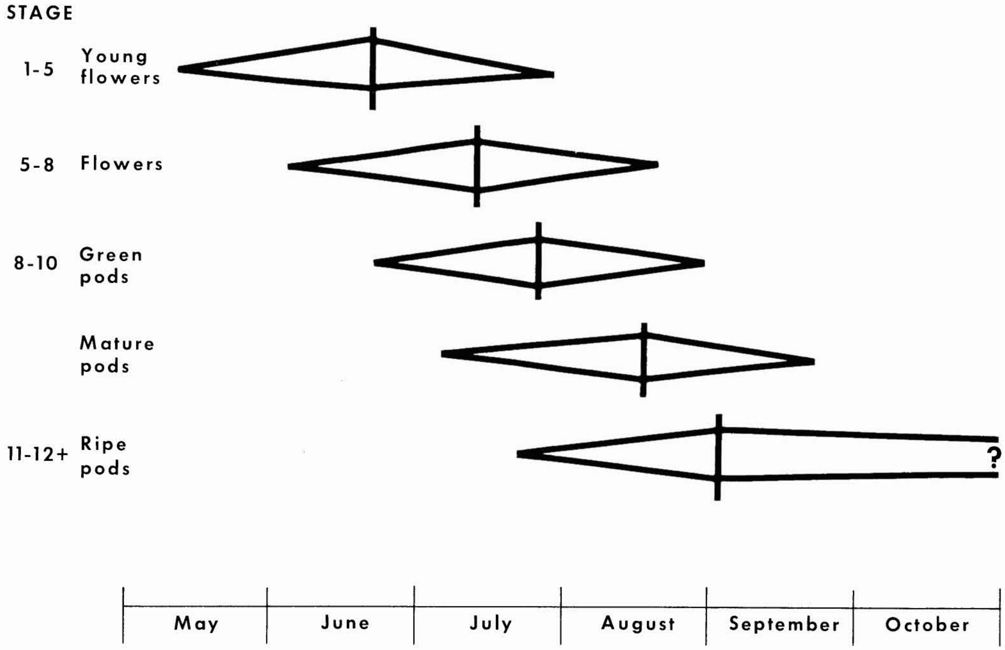

FIGURE 3. Estimates of the phenological events in the life cycle of the Hawaiian vetch based on observations of the 1977 growing season.

flowering individual, the ratio of flowering to nonflowering plants was 1:7.1, with a range from 1:1 to 1:30, or 11 percent of the 85 plants.

Phenology

We estimated the seasonal timing of events using as a baseline the date of transition from stage 9 to stage 10 (Figure 3). Transition occurred, on the average, on 31 July 1977. On the basis of these estimates, flower production began in mid-May of 1977 and probably peaked about 12 July 1977. On 31 May 1978, we observed clusters of flowers, only a few of which were to stage 5, confirming that flowering can occur as early as mid-May.

We observed the stages of flowering on the 4 plants described above (Table 2). The time required for development of small floral buds (stage 1) to mature flowers (stage 5) averaged 15.3 days. The flower appears mature an average of 7.9 days. Pod formation then begins in stage 7, after the petals have dropped over an average period of 4.6 days. Pod formation continues an average of 46.3 days from the start of stage 8 to the start of stage 12, when it is a mature dried pod. The entire process averages 74.1 days. Dehiscence of the pod usually occurs at the start of stage 12, with dispersal of the seeds shortly thereafter. Several mostly open pods, still containing seeds, however, were observed on dead plants in colony *F* in May 1978.

Pod growth was measured starting at stage 8 and was rapid for the next 15 days. Pods increased in average length from 80 mm to about 115 mm during this period (Figure 4). Growth rate then declined, and the pods reached a maximum average length of about 120 mm on about day 20. As the mature pods dried, they shrank at dehiscence to about 95 percent of their maximum size, about 40 to 50 days after the start of pod formation.

Although direct measurements of growth rates were not taken, the plants appeared capable of rapidly changing them. In 1978, plants known to be less than 1 year old were all less than 2 m in length. Three known individuals that were 1.6 m, 1.8 m, and 1.9 m

TABLE 2

PHENOLOGY OF FLOWER AND FRUIT PRODUCTION IN *Vicia menziesii*

STAGE	AVERAGE DURATION IN DAYS	SAMPLE SIZE	PHENOLOGICAL EVENT
1*	4.7	19	Floral bud small
2	3.6	37	Sepals open
3	3.4	72	Petals emerging
4	3.6	110	Petals green, not open
5	3.7	118	Petals green, open
6	4.2	111	Mature flower
7	4.6	64	Petals drop
8	4.3	42	Young pod
9	7.5	51	Green pod, glaucous
10	19.4	38	Sepals shrivelled
11	15.0	13	Seeds prominent
Total	74.1		

*See text for explanation.

in late summer of 1977 (probably at the end of the growing season), were found to be 2.5 m, 8.0 m, and 8.0 m, respectively, in May 1978. Thus growth rates can be highly variable.

Plant *E*1 (10.1 m in maximum length) was observed flowering in May 1977, and still had dried pods (about 8 m from the ground) from the 1976 season. It was flowering again in May 1978, although some branches had died. From these limited data it appears that *E*1 was a seedling at least in 1975, and quite possibly earlier. Further work now underway will clarify growth rates and longevity, but this study suggests that individual plants may survive at least 5 years and perhaps considerably more.

Reproduction

FLOWERS: Four representative flowering plants were observed closely enough to estimate the number of flowers produced. They were selected for their relative accessibility and their appearance—they appeared to be about as productive as the other 6 flowering plants. Not all parts of each plant could be viewed with equal ease, thus we sometimes had to estimate numbers and stages of racemes, flowers, and pods.

The 4 plants selected for observation produced approximately 39, 22, 10, and 11 racemes respectively, and each raceme usually had from 4 to 7 flowers, with an average of about 6. On the basis of these data, the plants would have produced approximately 235, 130, 60, and 65 flowers respectively, for a total of about 500 flowers. A number of flowers were found on the ground under these plants, beginning 20 July. Many were undoubtedly not counted, because they were either taken by rodents or lost in the undergrowth. About 337 were accounted for, more than one-half the estimated total.

If we assume that all 10 flowering individuals were equally productive, then all the colonies would have produced about 1250 flower during the 1977 season.

SEEDS: Individual seed pods are more visible and thus more easily quantified than flowers, and accurate counts were obtained on 8 plants. The average production was 26.2 pods per plant (Table 3), and assuming all plants were equally productive, about 260 pods were produced in the season. In the 4 plants closely studied, approximately 500 flowers produced about 115 seed pods, a 23 percent fruit set rate. If we assume equal productivity in all 10 flowering plants, then the 1250 flowers produced about 290 pods.

We collected seeds from 45 pods for growing in arboreta. Pods contained between 0 and 5 mature seeds ($\bar{x}$ = 2.56; SD = 1.14) and from 1 to 7 aborted seeds ($\bar{x}$ = 3.11; SD = 1.40). Thus, on the average, the 260 to 290 pods would have produced from about 670 to 735 mature seeds. The 4 arboreta receiving seeds reported to us differing viability rates, probably the result of differences in technique; 3 of the 4 rates were about 50 percent, and 1 was much lower. If survival and germination in the wild are similar, as many as 350 viable seeds were produced in this season. The seed coats are hard and, as is the case with the seeds of some other members of the pea family, possibly could survive many years if not eaten by rodents.

Damage and Mortality

Only one plant sustained probable cattle damage during 1977 when a single branch was eaten. Of the 85 plants, 8 (9.4 percent) had moderate to severe damage, with stems

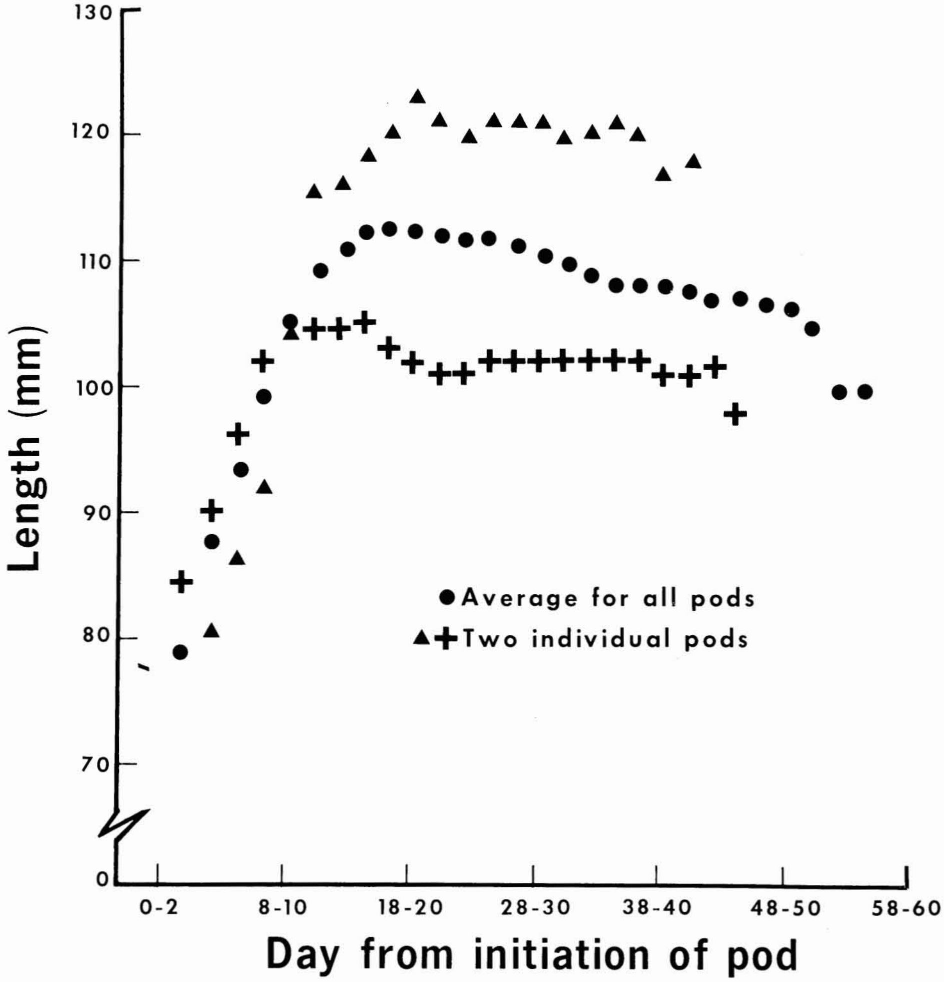

FIGURE 4. Average length of pods from the start of stage 8 represented as day 0. The start of later stages for plants for which no data were available for the start of stage 8 was derived from calculations in Table 2. Two individuals with complete records are also shown.

chewed or bitten off (Table 1). Because we have observed that the density of feral pig (*Sus scrofa*) was lower here than that in nearby areas, we ascribed the damage to mice (*Mus musculus*) or one of the species of rats (*Rattus* spp.) in the area.

In May 1978, 7 months after the October 1977 tabulation, mortality amounted to about 45 of the 85 individuals (52.9 percent) (Table 1). The uncertainty results from the fact that individuals were not marked, and therefore some may have been missed. These mortality data should be taken as tentative. For those plants less than 2 m in maximum length, mortality was 40.7 percent, and for larger plants, it was 57.7 percent. If we could assume that these plants were randomly selected from the population, these rates were significantly different ($P \leqslant 0.05$). Thus, mortality may be somewhat less in the smaller plants than in the larger and presumably older plants. The causes of this mortality are not known.

Use of Flowers by Birds

From 27 July to 11 August 1977, we spent approximately 20 hours observing flowering

TABLE 3

NUMBER OF FLOWERS AND PODS IN REPRODUCTIVE PLANTS IN ALL STANDS

PLANT NUMBER	MAXIMUM NUMBER FLOWERS*	MAXIMUM NUMBER PODS
C3	+	9
D13	ca. 250	18
E1	157+	32
F2	+	+
F15	+	20
F16	+	29
F17	+	38
F19, F20	150+	64
G11	+	+

* + indicates presence of flowers or pods which were not quantified.

TABLE 4

VISITS OF BIRDS TO FLOWERS OF HAWAIIAN VETCH PLANTS

PLANT	HOURS OBSERVED (APPROXIMATE)	NUMBER OF VISITS (NUMBER OF INDIVIDUALS)	
		ʻAmakihi	ʻIʻiwi
E1	1.7	1(1)	1(1)
F2	1.5	1(1)	0
G11	2.5	0	3(1+)
D13	14.5	19(4+)	0

plants (Table 4). We watched primarily 1 plant, but also 3 others. Two species of birds visited the flowers, the ʻIʻiwi (*Vestiaria coccinea*) and the ʻAmakihi (*Loxops virens virens*), members of the Hawaiian honeycreeper family, Drepanididae.

The birds fed on stage 5 and 6 flowers. The ʻIʻiwi would usually put its long (from 25 mm to 31 mm), decurved beak into the mouth of the corolla, often bending the flower upright from its usual hanging position. The ʻAmakihi seemed to be more destructive, with its shorter (from 12 mm to 17 mm), slightly downcurved beak. ʻAmakihi were tallied visiting individual flowers on 167 occasions. On 8 of these occasions (4.8 percent), flowers were seen to fall to the ground. This was not observed in about 50 flowers fed upon by ʻIʻiwi.

At least 4 ʻAmakihi were using vetch flowers. We identified these birds from color bands previously applied to their legs (Table 4). Three had territories that included the area around the plants, and one ʻAmakihi moved about 100 m from its territory to feed at the flowers.

The birds could be gathering either nectar, insects attracted to the flowers, or both. On the average, a bird visited 1 flower per 6.0 seconds and spent an average of 64.1 seconds at a stand (range was from 11 to 153 seconds). We found that the longer the elapsed time since the last bird had fed at the stand, the more time a subsequent bird would spend feeding at that stand (Figure 5). This suggests that a resource, probably nectar, was being replaced between visits.

DISCUSSION

Status

The Hawaiian vetch appears to be maintaining itself in the study area. The annual production of an estimated 350 viable seeds in the 1977 season indicates adequate reproduction. If we assume that all plants less than 2 m were plants germinated that season, as seems at least probable, then about 60 plants (70 percent) were new in 1977. About 53 percent of the total died over the winter; slightly more older plants died than younger. The reproductive rate is dependent, of course, upon the present level of fortuitous protection from grazing and continued relatively low populations of feral pig. The overall low numbers of the vetch, death rate of mature plants, very limited known range, and small reproductive population all indicate the need for protection to ensure the survival of the species.

The role of the birds in fertilization of vetch flowers must at this point remain speculative. No large flying insects, however, were seen to visit the flowers, although some could have been overlooked in the approximately 20 hours of daytime observation, or have been nocturnal. Some small drosophilid flies were observed on two occasions when flowers were closely examined, but these flies were not common.

Red flowers are generally assumed (e.g.,

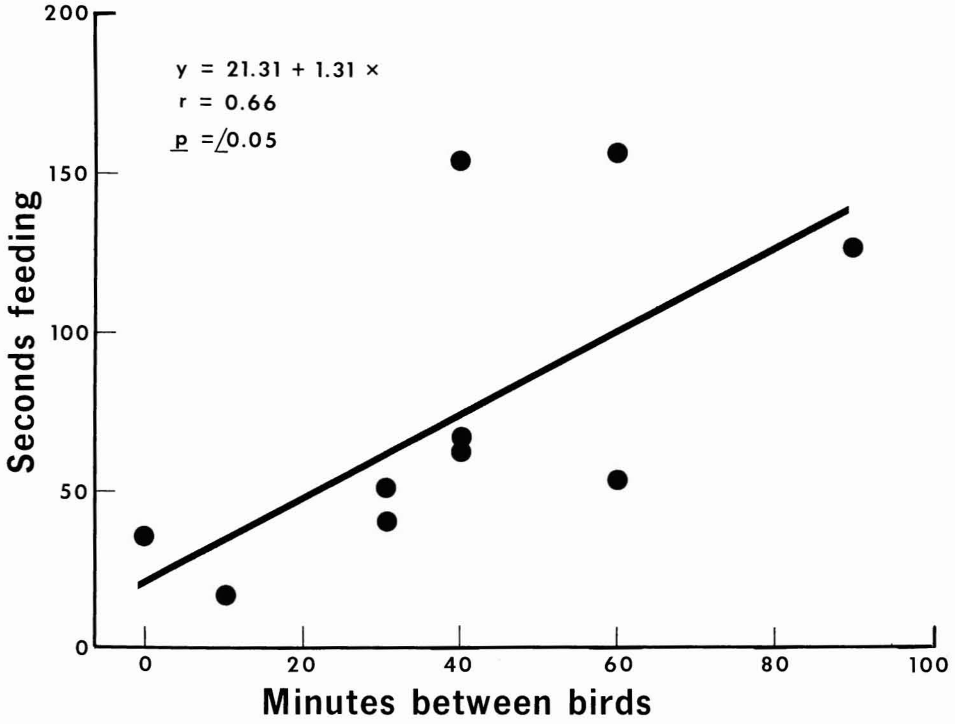

FIGURE 5. The length of time spent by birds feeding at flowers at a stand as a function of time since the last bird visited the stand.

Welty 1962) to be attractive to birds. The Hawaiian vetch is one of the few members of the genus to have red flowers, indicating that this might be an adaptation to ensure attraction to birds. Only 2 species of butterfly are native to Hawaii (Zimmerman 1958: v, 445), although the many species of moth and hymenoptera present could function as pollinators. The native birds certainly are attracted to the flowers and we show that they are probably taking nectar. These data at least suggest that the birds have a role in pollination of the vetch.

Future Status

If, as at least seems likely, the Hawaiian vetch was more widespread before the introduction of mammalian herbivores by the Polynesians and Europeans, we can speculate about the potential food production by this plant. The density of native birds in the forests near the study area now exceeds that of almost any region in the world (Ralph, unpublished data), possibly in part because of the copious production of nectar by the ʻōhiʻa-lehua. If the Hawaiian vetch had a much wider distribution in the past, the prolific flowers, palatable seeds and pods, and succulent vegetation could have been an important energy source for native fauna.

We can only hope that the species can be restored to a semblance of its former abundance, both for its considerable esthetic qualities and for its food value to wildlife.

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